Testing Psychological Reality of Complex Units with XOR Learning

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Abstract

What are the units stored in the lexicon? On the lexical level, there is disagreement about the storage of morphemes (e.g., Bybee 1985, Stockall and Marantz 2006), regularly inflected words (e.g., Bybee 1985, Pinker 1999), and high-frequency phrases, prefabs (Bybee and Scheibmann 1999, Solan et al. 2005). On the sublexical level, there is disagreement about the psychological reality of segments (Port and Leary 2005, Nearey 1997), rimes (Kessler and Treiman 1997, Yoon and Derwing 2001, Pierrehumbert and Nair 1995, Vennemann 1988), and syllables (Ferrand et al. 1996, Schiller 1997). This paper introduces a new method for testing psychological reality of potentially decomposable linguistic units, XOR learning. We show that English speakers learn associations of rimes better than they learn associations of bodies, suggesting that the rime is a unit in English while the body is not.

Definitions

- **XOR learning**: the whole is associated with a different response than both of its parts.

  A → X
  B → X
  AB → Y

  This distribution cannot be learned by a model that only has representations for A and B and no separate representation for AB (Minski and Papert 1969).
- A **complex unit** is represented by a node or set of nodes that are not involved in representing either one of the units it is composed of.
- A **node** is something that can be associated.

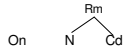
Three models of constituency

1. Constituency is connection strength (e.g., Vennemann 1988).

On —— N ——Cd

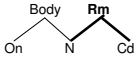
Prediction: Learning On, N, Cd associations should be much easier than learning body and rime associations.

2. Constituency is unit formation (e.g., Yoon and Derwing 2001).



Prediction: Rime associations should be easier to learn than body associations.

3. Constituency is unit prominence (Bod 1998).



Prediction: **Associations of both rimes and bodies should be relatively easy to learn. Associations of bodies may be easier to learn** than associations of rimes: bodies have lower resting activation level and units with high resting activation levels are hard to associate (Moder 1992, Hall 2003).

Research Questions

- Are rimes more or less associable than bodies?
- Can English speakers associate both rimes and bodies?
- Are segments more associable than rimes and bodies?

Methods

Subject groups

4 groups of subjects (17 subjects/group) learn associations between

rime { –Group 1 coda-prefix, nucleus-prefix, rime-prefix
rime { –Group 2 coda-suffix, nucleus-suffix, rime-suffix
body { –Group 3: onset-prefix, nucleus-prefix, body-prefix
body { –Group 4: onset-suffix, nucleus-suffix, body-suffix

Regularities to learn

–**Groups 1 & 2** (each group learns both sets below)

CæC→num	CʌC →mɪn
ʃVC →num	gVC →mɪn
BUT ʃæC→ mɪn	BUT gʌC → num

- **Groups 3 & 4**

CæC→num	CʌC →mɪn
CVʃ →num	CVg →mɪn
BUT Cæʃ→ mɪn	BUT Cʌg → num

Due to this setup, learning associations of the parts does not help learning associations of the wholes.

Procedure

Part 1: Only V and C training

Stimuli heard: fuʃ, fiʃ, foʃ
Stimuli not heard: fæʃ, luʃ, liʃ, luʃ

– Training – listen to word-affix pairs (74 pairs)
– Feedback (40 pairs)
  Listen to word-noise or noise-word pairs
  Press a button ('min' or 'noom')
  Listen to the correct word-affix pair
  e.g., fuʃ-NOISE → subject presses a button → fuʃ-num.
– Generalization 1 (56 pairs) –
  Listen to word-noise or noise-word pairs with words never hears before
  e.g. luʃ-NOISE (/l/ not used in training)
  Press a button ('min' or 'noom')

Part 2: V, C, and Whole (either rime or body) training

fæʃ now presented during training and feedback

Training → Feedback → Generalization 2
Training → Feedback → Generalization 3
Generalization 3 = Generalization 1

Predictions Reviewed:

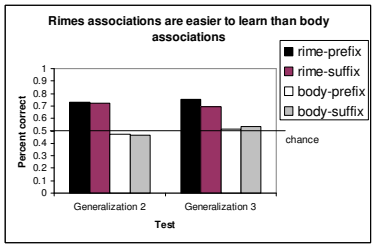
Model 1 → bodies are more associable than rimes; both are less associable than segments

Model 2 → Rimes are more associable than bodies.

Model 3 → Both bodies and rimes can be associated with other units. Bodies should be more associable because rimes are more prominent and prominent units tend to be less associable.

Results

- **Subjects can learn rime-affix associations but not body-affix associations (p<.005)**
- **only rime associations generalize to novel syllables.**



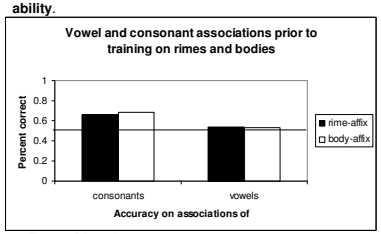
It could be the case that learning coda associations is harder than learning onset associations and thus that learning rime associations is easier than learning nody associations because coda associations do not interfere as much as onset associations.

→ look at associability of onsets vs. codas at the test that precedes training on rimes and bodies

Codas and onsets do not differ in associability → the body/rime difference could not be due to an onset/coda difference.

Are some subjects simply better learners than others? All groups of **subjects are equal on learning vowel-affix associations**

→ differences seen with learning rime-affix and body-affix associations cannot be due to individual differences in learning ability.



Model Evaluation

Results support Model 2

Subjects learn rime-affix but NOT body-affix associations
→the rime is a unit in English
→the body is not (contra model 3)
(there are nodes assigned to representing rimes but not bodies).

Future work: It is possible to salvage Model 3 if we change it to claim that bodies are less associable than rimes because they are easier to parse out of the signal, i.e., both bodies and rimes are units but parsing is not obligatory.

Suffixes are not more associable than prefixes (contra Cutler et al. 1985, Hall 1992;pro Bybee et al. 1990).

No locality effect: rime-suffix = rime-prefix.

Model Evaluation

Model 1:
Cd-N stronger than On-N
Stimuli with strong associations are less associable
(Blocking Principle: Kamin 1969)
→codas should be less associable than onsets
Rejected. Codas and onsets are equal in associability.

→C's and V's are more associable than rimes or bodies
Rejected. Rimes are more associable than vowels.

Future Directions

1. **Rimes vs. bodies or CV vs VC?** The next step is to look at **CV.CV words**. If associability is due to unithood, CV's should be more associable than VC in such stimuli.
2. Do the results hold for **tense vowels**?

Conclusion

XOR learning is a useful tool for studying the nature of constituency. It has wide applicability to issues in the mental lexicon, phonology, morphology, and syntax. In this paper we have shown that rimes are more associable than bodies, a result that supports the traditional model of the English syllable and localist representation in general. The existence of vowels as separate units is, however, in question.

Further controls

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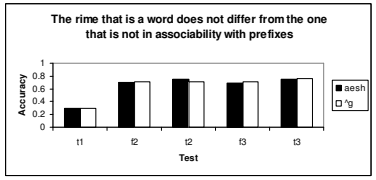
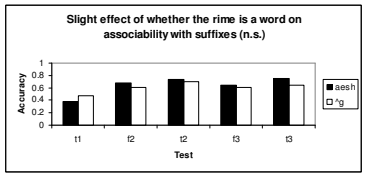
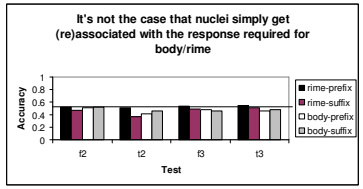
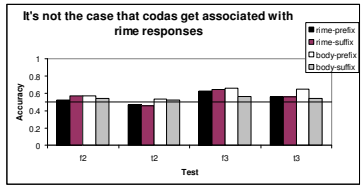
If the rime/body difference was due to the fact that 'ash' is a word, we would expect the two rimes 'ash' and 'ug' to show differences in associability. The figures below show that they do not.



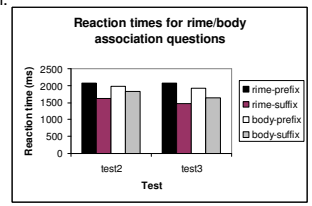


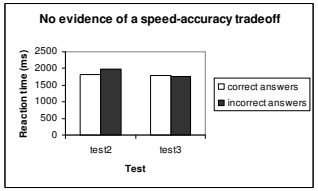
If rime associations were illusions generated by segment associations, accuracy on segments would fall significantly below chance when rime associations are introduced into training. The figures below show that this does not happen.



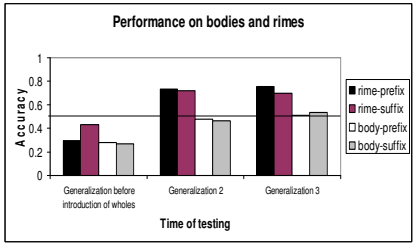


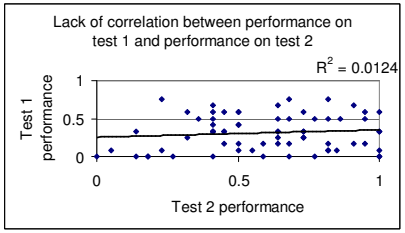
Reaction times are faster for suffixes because the second part of a test stimulus on suffix trials is uninformative noise. There is no effect of constituency.





It is not the case that rime and body associations improve by the same amount as a result of training. Even though rime-suffix condition sticks out pre training on wholes, there is no correlation between performance on wholes prior to after training.





N.B.: These particular rimes and bodies were chosen so that the rime would not be less frequent than the body, since frequent units are less associable and so that codas and onsets do not differ in frequency of occurrence. Frequency estimates were obtained from the MRC Psycholinguistics Database (Coltheart 1981), the Hoosier Mental Lexicon (Nusbaum et al. 1984) and Kessler and Treiman (1997).

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